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# Conceptual Design of a Small Helicopter

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**Abstract:** The purpose of the study is to propose a conceptual design process by developing the aircraft from the scratch and to optimize the design using a structured approach. As part of this study, a concept for a small helicopter was developed. From this study, the main parameters to be had for conceptual phases is the maximum take-off weight, maximum rotor diameter, engine to be used, major drawing for proposed design, and centre of gravity envelope. Due to assumed simplicity of the rotor design and taking into account some technological constraints, the main approach for the conceptual design is by dedicating design which would influence satisfactory improvement in a performance of a small helicopter from parametric study and pre-existing specifications. The results obtain from this study will be the benchmark and within the constraints of further improvement. From this study, preliminary stages of development for small helicopter are critical in reviewing and modifying the future aircrafts.

**Keywords:** Conceptual Design, Small Helicopters, Major drawing, center of gravity

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## 1. Introduction

Helicopters is a type of rotorcraft in which horizontally supply lift and thrust. On the other name it is any of a class of heavier-than-air craft and sustained in the air horizontally by rotating wings or blades turning on vertical axes through power supplied by an engine. The fact that the helicopters obtain its lifting power by means of a spinning air foil greatly complicates the factors influencing its flight, since the rotor not only spins but also travels up and down in a flapping motion and is influenced by the helicopter's horizontal and vertical movement.

While small helicopter or often called ultralight helicopter, does not differ much from regular-sized helicopter, they are built much lighter, easier to operate and have the same functionality as regular-sized helicopter. Furthermore, if we take performance parameters and design specification, we can see that small helicopter is way better than regular-sized helicopter in various terms. The small helicopters can maintain optimum flight speed with high safety and maneuver in tight spaces. Small helicopter also has very stable flight performance due to their lower weight, which translates into lower inertia and vibration.

Small helicopter has been increasing in its production and widely used for many various operations whether it is commercial or domestic operation. In developed countries such as Britain, a large percentage of small helicopter is owned by civilian as small helicopter is more economic and logistical; small helicopters are very agile in their movement, maneuvers easily in tight spaces and has wider choice of landing places. If the development of small helicopter in Malaysia is widen and continue, we can see a rise in number of owners for these helicopters.

In this study, a conceptual design of a small helicopters will be choose based on some parameters such as maximum take-off weight, main rotor diameter, engine selection and major drawing. This study will focus on the all ideas and specifications that can be used to categorized and specifies a small helicopter.[3] Using pre-existing parameters from sample helicopters and estimation to be used, a conceptual design can be chosen and finalized.

## 2. Methodology

The methodology used in this study is mostly by using parametric study based on pre-existing helicopters. The pre-existing helicopters can be important parameters to estimate the conceptual design that will be created. [2]

### 2.1 Parametric Study

The pre-existing helicopters that are to use for the study is from 20 sample helicopters from various shape and size that are still within the limit of small helicopter. The position of the body parts and tail parts are also based on the sample helicopters to be used for major drawing of the small helicopters. A list of 20 helicopters that are categorizes as small helicopters will be listed in the following table.

**Table 1: List of sample small helicopters**

| No | Rotorcraft |
|---|---|
| 1 | Mosquito Aviation Xe |
| 2 | Revolution Mini-500 |
| 3 | Helicycle N727X |
| 4 | Konner K1 |
| 5 | Dynali H3 EasyFlyer |
| 6 | Heli Sport Ch-7 |
| 7 | LCA LH 212 Delta |
| 8 | Hungaro Copter |
| 9 | Alfi Syton AH 130 |
| 10 | SKT Skyrider |
| 11 | DF-334 |
| 12 | Robinson R22 |
| 13 | Youngcopter Neo |
| 14 | Aerokopter AK1-3 Sanka |
| 15 | Rotorway Exec |
| 16 | Curti Zefhir |
| 17 | Robinson R44 |
| 18 | Robinson R66 |
| 19 | Bell 47 |
| 20 | Boeing MH-6M Little Bird |

The parameters that are to be used based on this small helicopter are maximum take-off weight, main rotor diameter and engine selection.

## 2.2 Methods

The maximum take-off weight and main rotor diameter will be calculated by using average from 20 sample helicopters. The graph will be used by plotting maximum take-off weight vs rotorcraft and main rotor diameter vs rotorcraft. From the graph, the line of best fit will be used to determine the average of the value from parametric study that are being carried out. The engine selection will be chosen by using the engine that are commonly used and standardized engine by the 20 sample helicopters.

In order to determine the centre of gravity envelope, we can list down all the components on the helicopters using estimate position. The length and size of the helicopters in x-axis and y-axis is 10.0m and 2.30m respectively. The length and height of the helicopters is assumed as the parameters does not vary much from numerous sample helicopters. This also apply to the position and weigh of the components of the small helicopters. The Solidworks 2019 will be used to design and produce major drawing of the small helicopters. The drawing will be started by drawing the body frame. Next, the main rotor which closely follows byrotor blades and lastly the tail parts. The shape and size of the helicopters will be estimate by using the 20 sample helicopters as the sample helicopters does not differ very much from each other.

## 3. Results and Discussion

The results and discussion section presents data and analysis of the study. This section can be organized based on the objectives, aim of the study, methodology that are mentioned in methods, estimation and calculation.

### 3.1 Results

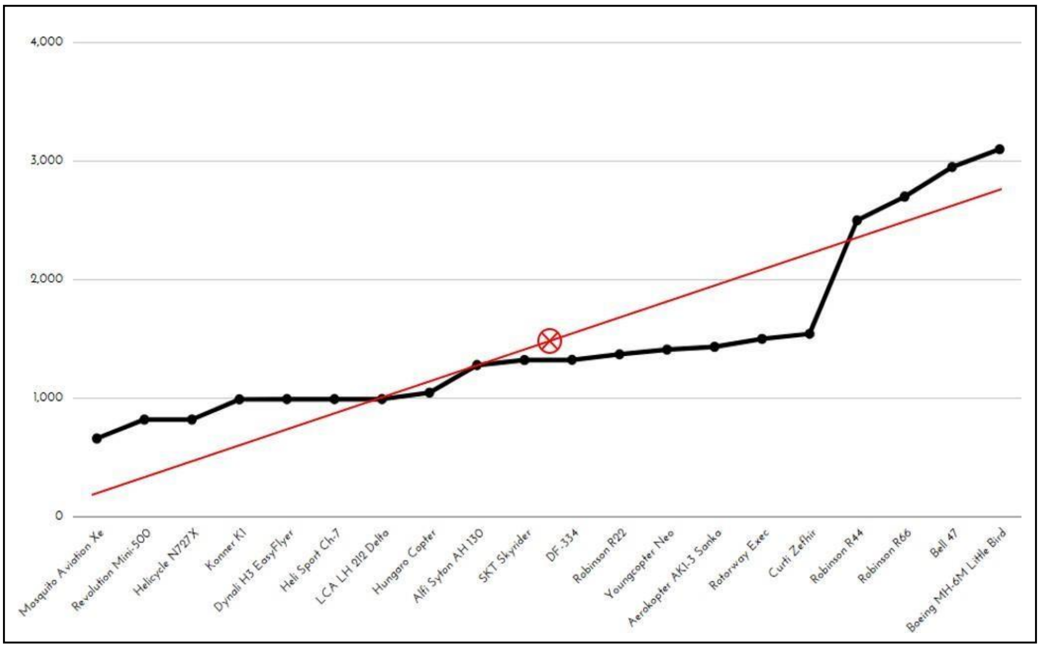


**Figure 1: Maximum Take-off Weight vs Rotorcraft**

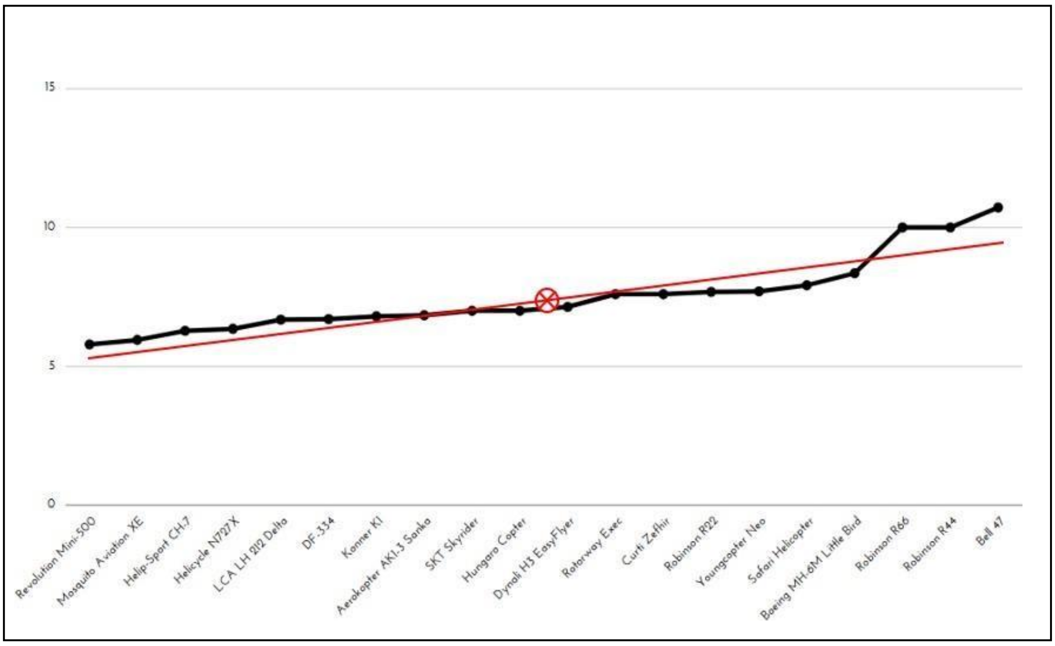


**Figure 2: Main Rotor Diameter vs Rotorcraft**

From the estimation of the maximum take-off weight, it can be seen that the most optimal maximum take-off weight is 1487.15 lbs. From the estimation of the main rotor diameter, the best main rotor diameter that are choose is 7.49m. The estimation of these two parameters must be within the regulations of FAA (FAR 27) which states that small helicopter must be in the range of between 700 lbs to 1600 lbs. [3] The main rotor diameter also must not exceed 10m as this will make the designing process to be much harder and will make the size and shape of the helicopters slightly larger than pre- existing small helicopters.[4]

**Table 2: Calculation for Centre of Gravity Envelope**

| No | Components | Weight (lbs) | X-axis (m) | x • W (m•kg) | Y-axis (m) | y • W (m•kg) |
|---|---|---|---|---|---|---|
| 1. | Main Rotor | 320 | 2.65 | 747.94 | 0.82 | 262.4 |
| 2. | Tail Rotor | 264 | 8.82 | 2328.48 | 1.51 | 398.64 |
| 3. | Gearbox | 320 | 2.68 | 857.6 | 1.59 | 508.8 |
| 4. | Engine | 154 | 3.72 | 572.88 | 1.20 | 348.04 |
| | Total | 794 | | 4506.90 | | 1517.88 |

Approximate location centre of gravity of empty small helicopter can be produced by using theformula as below;

$$\boldsymbol{x} = \frac{x - coordinate}{total\,weight}$$

$$x = \frac{4506.90}{794}$$

$$= 5.676\text{m}$$

$$\boldsymbol{y} = \frac{y - coordinate}{total\,weight}$$

$$y = \frac{1517.88}{794}$$

$$= 1.911\text{m}$$

3.2 Discussion

The engine that will be selected will be Rotax 914. The parametric study shows that the 4 out of 20 rotorcraft is using Rotax 914 and this engine has the optimum power and gross weight which is 115hp and 172lbs respectively. Rotax 914 can be used as a benchmark whether to increased or lower the power for performance as Rotax 914 is the most optimum out of other engines. Rotax 914 also follows the regulations FAA (FAR27) which is turbocharged engine, four stroke, four cylinders with air-cooled cylinders.

Figure 3 shows the approximate location for centre of gravity by using the weight distribution series. The only main issue for the centre of gravity is that many of the parameters used is based on assumption and need to be iterated for future research. Since this study in the conceptual designing process, the major drawing in the Figure 4, Figure 5, Figure 6 and Figure 7 is based on existing small helicopters and the size and shape is tweaks by making fine adjustment to it until all of these parameters will come together when they are assembled. This major drawing will be used for future fabrication by adjusting the components size and shapes to be suited with more concise and accurate calculation and iterations.

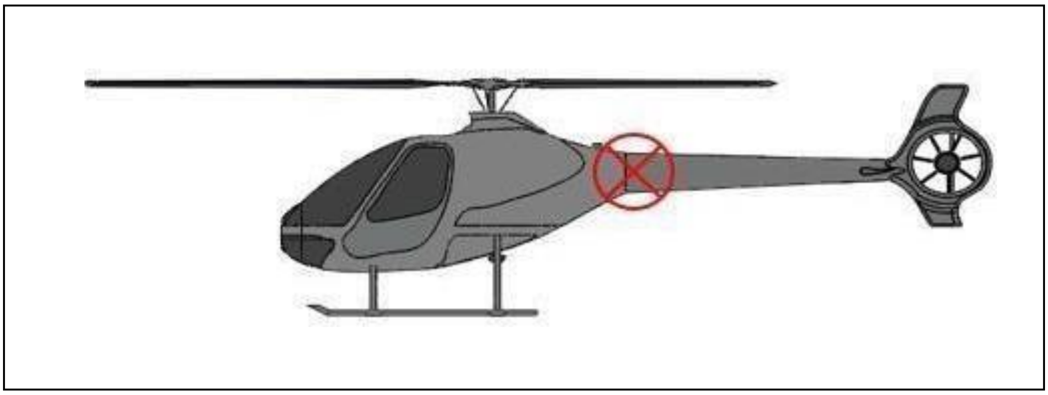

**Figure 3: Approximate Location of Center of Gravity**

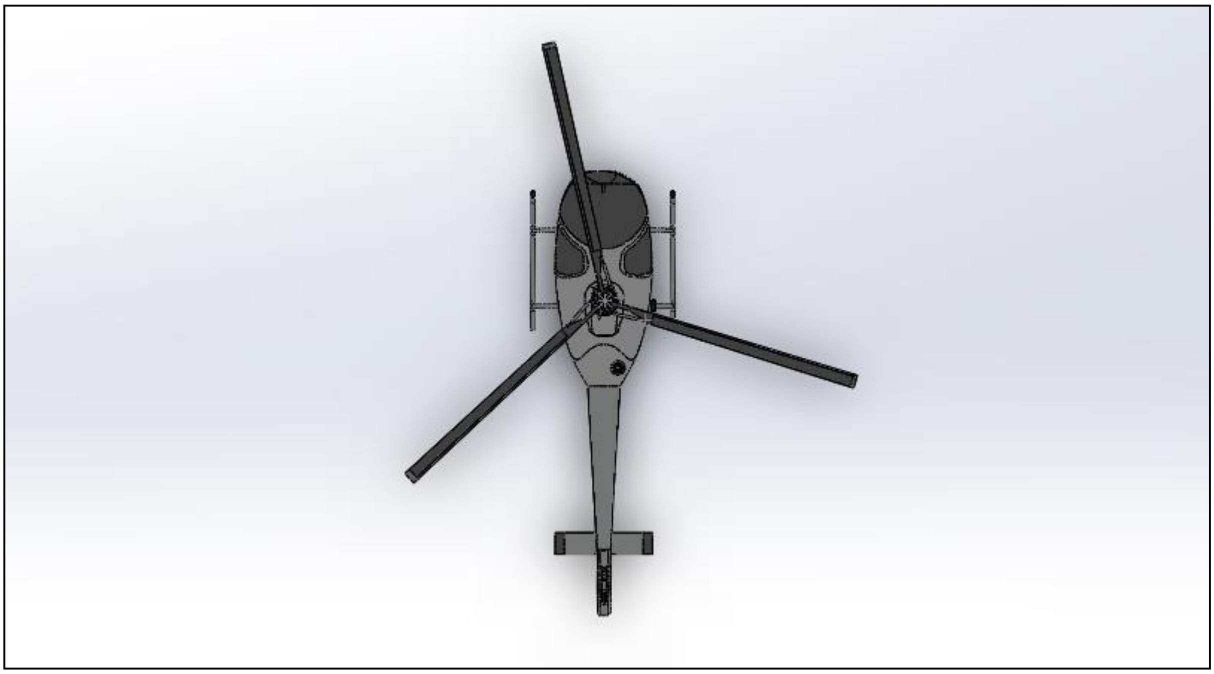

**Figure 4: The Top View of Helicopter Drawing**

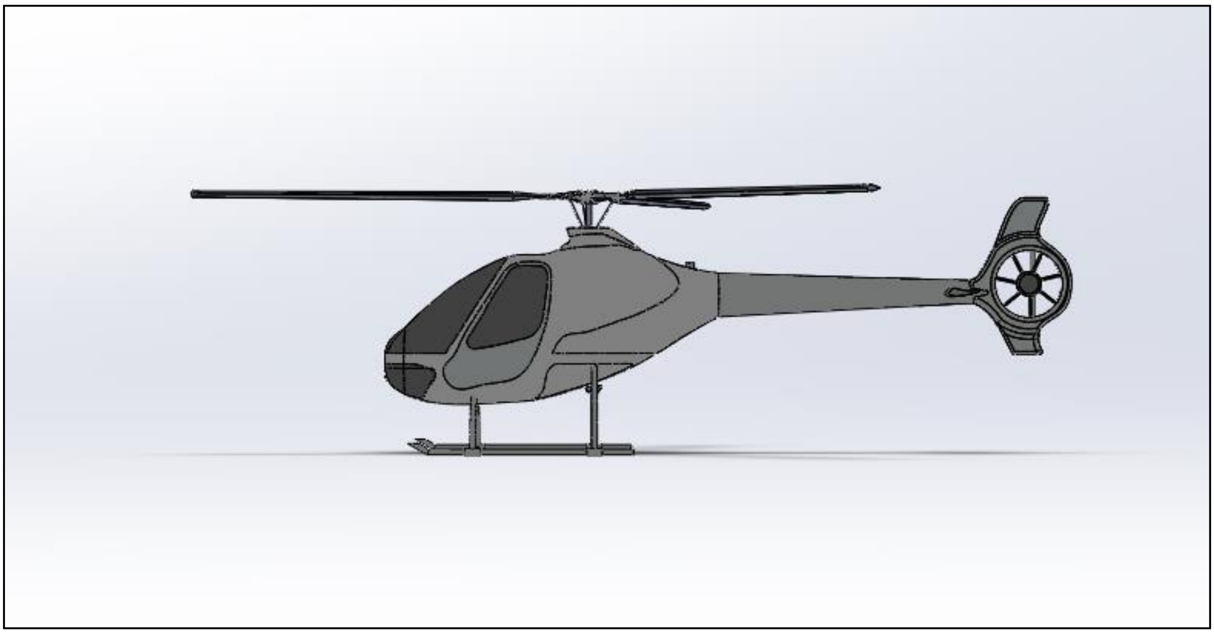

**Figure 5: The Side View of Helicopter Drawing**

Figure 6: The Front View of Helicopter Drawing

**Figure 7: The 3-D View of Helicopter Drawing**

## 4. Conclusion

The aim of this study is so that the conceptual design that are calculated are to be used for further research is achieved. The objective of this study also achieved as the conceptual design of the small helicopters follows and within the regulation of FAA (FAR27) which indicates that the helicopters in this study is considered as a small helicopter. Main parts of this study are maximum take-off weight, main rotor diameter, engine selection and drawing design is included in this study as a parameter that need to be calculated in this conceptual design. The accuracy of the maximum take-off weight, main rotor diameter and engine selection and major drawing are still in the early stages of designing and more research need to be conducted to be use for future research.[5]

Recommendation can be made to increase the better overall conceptual design by applying more parameters such as disk loading and air foil. Performance analysis such as hover, forward flight and vertical climb can also be included so that the performance analysis can be a part of the conceptual design. Economic factors are available for this study as small helicopters are used for various purposes thus may benefit the future research.

## Acknowledgement

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## Appendix A

**Table A-1: Maximum Take-off Weight vs sample helicopters**

| No | Rotorcraft | Maximum Take-off Weight (Lbs) |
|---|---|---|
| 1 | Mosquito Aviation Xe [7] | 660 |
| 2 | Revolution Mini-500 [8] | 820 |
| 3 | Helicycle N727X [19] | 820 |
| 4 | Konner K1 [11] | 990 |
| 5 | Dynali H3 EasyFlyer [6] | 992 |
| 6 | Heli Sport Ch-7 [15] | 992 |
| 7 | LCA LH 212 Delta [21] | 992 |
| 8 | Hungaro Copter [17] | 1047 |
| 9 | Alfi Syton AH 130 [13] | 1279 |
| 10 | SKT Skyrider [12] | 1322 |
| 11 | DF-334 [14] | 1323 |
| 12 | Robinson R22 [3] | 1370 |
| 13 | Youngcopter Neo [18] | 1410 |
| 14 | Aerokopter AK1-3 Sanka [16] | 1433 |
| 15 | Rotorway Exec [20] | 1500 |
| 16 | Curti Zefhir [13] | 1543 |
| 17 | Robinson R44 [4] | 2500 |
| 18 | Robinson R66 [5] | 2700 |
| 19 | Bell 47 [9] | 2950 |
| 20 | Boeing MH-6M Little Bird [10] | 3100 |

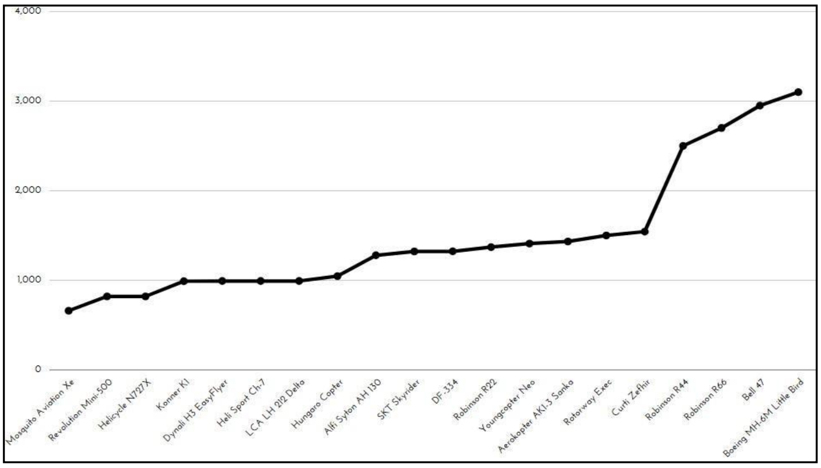


**Figure A-1: The graph of Maximum Take-off Weight vs Sample Rotorcraft**

**Table A-2 Main Rotor Diameter vs Sample Rotorcraft**

| No | Rotorcraft | Main Rotor Diameter (m) |
|---|---|---|
| 1 | Revolution Mini-500 | 5.79 |
| 2 | Mosquito Aviation XE | 5.95 |
| 3 | Heli-Sport CH-7 | 6.28 |
| 4 | Helicycle N727X | 6.35 |
| 5 | LCA LH 212 Delta | 6.68 |
| 6 | DF-334 | 6.70 |
| 7 | Konner K1 | 6.80 |
| 8 | Aerokopter AK1-3 Sanka | 6.84 |
| 9 | SKT Skyrider | 7.00 |
| 10 | Hungaro Copter | 7.00 |
| 11 | Dynali H3 EasyFlyer | 7.14 |
| 12 | Rotorway Exec | 7.60 |
| 13 | Curti Zefhir | 7.60 |
| 14 | Alfi Syton AH 130 | 7.63 |
| 15 | Robinson R22 | 7.68 |
| 16 | Youngcopter Neo | 7.70 |
| 17 | Boeing MH-6M Little Bird | 8.35 |
| 18 | Robinson R66 | 10.00 |
| 19 | Robinson R44 | 10.00 |
| 20 | Bell 47 | 10.72 |

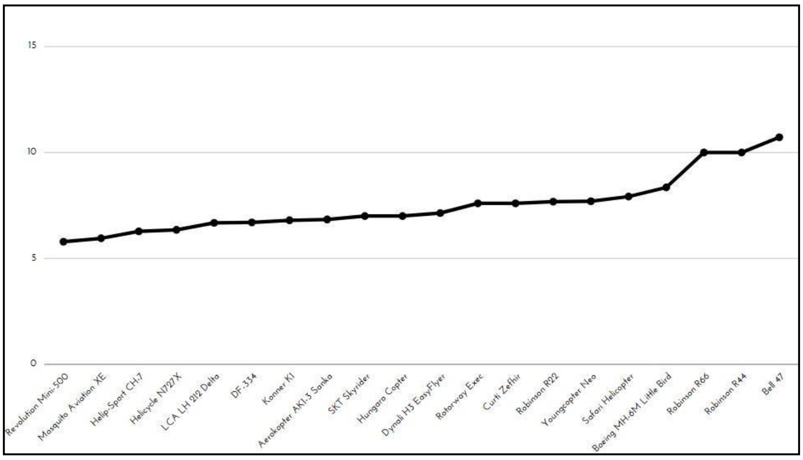


**Figure A-2: The graph of Main Rotor Diameter vs Sample Rotorcraft**

**Table A-3 Engine Choices for Selection from Sample Helicopters**

| No | Rotorcraft | Turbocharged Engine Used | Power Produce (hp) | Gross Weight (lbs) |
|---|---|---|---|---|
| 1 | Revolution Mini-500 | Rotax 582 | 64 | 73 |
| 2 | Mosquito Aviation XE | MZ202 | 64 | 84 |
| 3 | Konner K1 | Konner TK250 | 250 | 110 |
| 4 | Curti Zefhir | PBS TS100 | 241 | 125 |
| 5 | Boeing MH-6M Little Bird | T63-A-5A | 252 | 138 |
| 6 | Alfi Syton AH 130 | Solar T62 | 130 | 142 |
| 7 | Helicycle N727X | Solar T62 | 150 | 142 |
| 8 | Rotorway Exec | Solar T62 | 150 | 142 |
| 9 | DF-334 | Rotax 914 | 115 | 172 |
| 10 | Dynali H3 EasyFlyer | Rotax 914 | 115 | 172 |
| 11 | LCA LH 212 Delta | Rotax 914 | 115 | 172 |
| 12 | Heli-Sport CH-7 | Rotax 914 | 115 | 172 |
| 13 | SKT Skyrider | MW Fly B22 | 155 | 176 |
| 14 | Robinson R66 | Rolls Royce RR3000 | 270 | 201 |
| 15 | Aerokopter AK1-3 Sanka | Subaru EJ25 | 156 | 265 |
| 16 | Hungaro Copter | Subaru EJ25 | 160 | 265 |
| 17 | Robinson R22 [25] | Lycoming O-320 | 124 | 275 |
| 18 | Youngcopter Neo | Neosis Wankel | 180 | 352 |
| 19 | Bell 47 | Lycoming TVO-435 | 280 | 433 |
| 20 | Robinson R44 | Lycoming IO-540 | 280 | 540 |

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